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Original communication

Sex determination using anthropometric dimensions of the clavicle in Iranian population

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ABSTRACT

Objective: Sometimes only skeletal remains are available for forensic identification. Therefore, sex determination using human skeletal remains is one of the most important components in forensic identification. Different levels of accuracy for sex determination using clavicle have been reported in various studies, and on the other hand, anthropometric dimensions of different bones are unique in each race and geographical region. This study was carried out to assess the accuracy of this bone for sex determination in Iranian population. Based on the results of this research, by using the anthropometric dimensions of the clavicle bone, gender can be estimated with a high accuracy.
Materials and methods: This research was carried out on 120 Iranian cadavers. Maximum of length and midshaft circumference of clavicle was measured. SPSS (Version 13.5) was used for statistical analysis.
Results: The mean of maximum of the length and the midshaft circumference of clavicle was larger in men ($P < 0.001$). Using claviclular anthropometric parameters, we could determine sex with 73.3%–88.3% accuracy.
Conclusion: The results of this research indicate that sex can be determined using clavicle dimensions with relatively high accuracy, when only the clavicle bone is available due to explosion, plane crashes, mutilated bodies, etc.

1. Introduction

The cadavers sent to forensic pathology center to determine their identity are not always intact. Therefore, sometimes in case of plane crashes, natural disasters, explosions, etc., only skeletal remains or some parts of the human body are available for identification.[1,2]

In previous studies, some skeletal remains such as pelvis,[3] skull,[4,5] upper and lower limb bones,[6,7] sternum,[8] patella,[9] foot bones[10] and clavicle[11–16] have been used for identification.

Clavicle is among long bones and it is relatively resistant against environmental corruption and degradation. However different accuracy of sex determination using this bone has been reported in literature, and on the other hand, anthropometric dimensions of different bones are unique in each race and geographical region.[17] Therefore this study was carried out to assess the accuracy of this bone regarding the gender differentiation in Iranian population.

2. Materials and methods

This research was carried out on 120 Iranian cadavers over 20 years old in autopsy hall of Legal Medicine Organization of Iran (L.M.O) in Tehran during 2009 and 2010. Sample size was calculated using following formula:

$$n = \frac{\left(Z_{1-\alpha/2} + Z_{1-\beta}\right)\left(S_1^2 + S_2^2\right)^2}{\left(\overline{X}_1 - \overline{X}_2\right)^2}, \quad \alpha = 0.05, \ \beta = 0.2 \qquad (1)$$

Where S_1 (=7.99^2) and S_2 (=10.66^2) are the clavicle's length variances for female and male respectively. $\overline{X}_1 (= 140.2)$ and $\overline{X}_2 (= 158.2)$ are the average values for the length of clavicles

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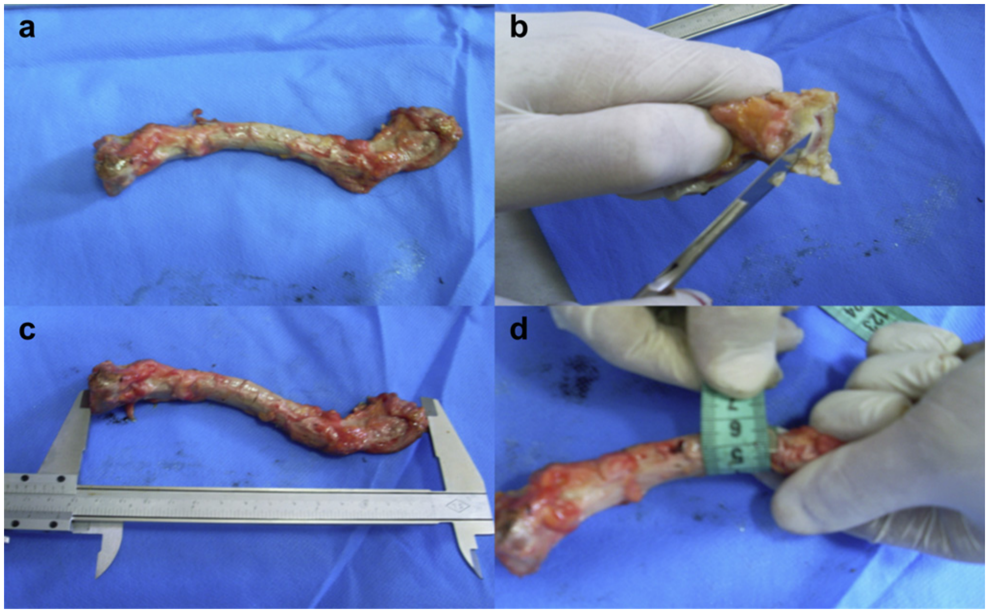

Fig. 1. Measurement steps (a) separated clavicle bone sample (b) preparing the separated bone for measurement (c) maximum length of the clavicle measurement (d) Maximum midshaft circumference of clavicle measurement.

for females and males respectively gives the n value, sample size, about 40. To improve the accuracy of the study, the sample size was increased to $n = 60$ for each gender, females and males.[18]

Cadavers with unknown identity, left clavicle fracture, and any congenital or acquired bone abnormality, leading to change in the bone anatomy, were excluded. Routine autopsy was carried out on the samples. After taking written informed consent from relatives, without additional cut on cadaver skin, a scalpel used to complete separation of the left clavicle bone from medial and lateral joints. Then after complete separation of soft tissue, the cartilage was carved at two ends of the clavicle till epiphysis was shown up. Thereafter maximum length of clavicle was measured using caliper in millimeter and its circumference was measured by determining the midpoint of clavicle bone with a flexible metal tape in millimeter scale. After complete separation of clavicle from the selected cadaver and measuring its dimensions, the separated clavicle was returned to its original anatomic place and the skin was reconstructed that is illustrated in Fig. 1.

After data collection, statistical analysis was performed using the SPSS (Version 13.5). Descriptive (frequency-descriptive) and analytical statistical tests (t-test) and logistic regression model were used.

Table 1
Comparison of clavicle diameters between two sex (in mm).

Clavicle Parameters	Sex	Mean	SD	95% CI		Min	Max
				Lower Bound	Upper Bound		
MLC[a]	Male	147.208	10.374	144.528	149.888	126.1	168.2
	Female	130.370	8.609	128.146	132.594	103.4	158.1
	Total	138.789	12.711	136.491	141.087	103.4	168.2
MMCC[b]	Male	44.07	5.358	42.68	45.45	28	59
	Female	38.38	5.260	37.02	39.74	32	62
	Total	41.23	6.008	40.14	42.31	28	62

[a] MLC: Maximum Length of Clavicle.
[b] MMCC: Maximum Midshaft Circumference of Clavicle.

3. Results

The maximum of length and circumference of clavicle shaft were assessed in 120 fresh cadavers including 60 men (50%) and 60 women (50%). In this paper, the maximum length of clavicle and midshaft circumference are referred as MLC and MMCC, respectively. The descriptive statistics of the MLC and MMCC from acquired data are presented in Table 1.

The mean value of the MLC and MMCC was larger in men ($P < 0.001$) (Figs. 2 and 3). Furthermore, the mean sum of these two parameters(i.e. MLC + MMCC) was greater in men ($P < 0.001$).

The population under study was divided into three age groups: less than 40 years old (included 39 cases, 20 men and 19 women), 41–60 years old (included 39 cases, 20 men and 19 women), and older than 60 years (included 42 cases, 20 men and 22 women). The descriptive statistics of MLC and MMCC at different age groups are shown in Table 2.

There was no significant difference in either MLC and MMCC or the sum of these two parameters ($P > 0.05$) among different age groups.

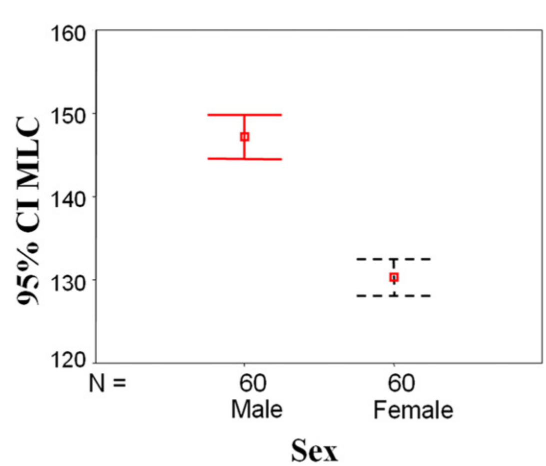

Fig. 2. Comparison of the maximal length of clavicle (MLC) between male and female (95% CI).

Based on the following formula,[19] the Demarking point (DP) was calculated for MLC and MMCC:

$$DP = \frac{\{\text{mean} + \text{three standard deviation (women)}\} + \{\text{mean} - \text{three standard deviation (men)}\}}{2} = \frac{(\mu + 3\sigma)_{\text{Women}} + (\mu - 3\sigma)_{\text{men}}}{2} \quad (2)$$

where μ and σ are mean and standard deviation, respectively. Using ROC curves, the sensitivity and specificity of each parameter at the mentioned D.P for gender determination was calculated which are shown in Table 3. The results obtained from the relation between clavicle dimension and sex at different age groups are explained.

There was a significant difference in the maximum length of clavicle between two sexes in all defined age groups (*P* value is 0.001, 0.00 and 0.00 respectively) that is shown in Fig. 4. However regarding the MMCC, there was a significant difference between two sex only in age group above 60 years old ($P = 0.002$), where the results are shown in Fig. 5. There was no significant difference in other age groups ($P = 0.082$ for under 40 years old and $P = 0.319$ in

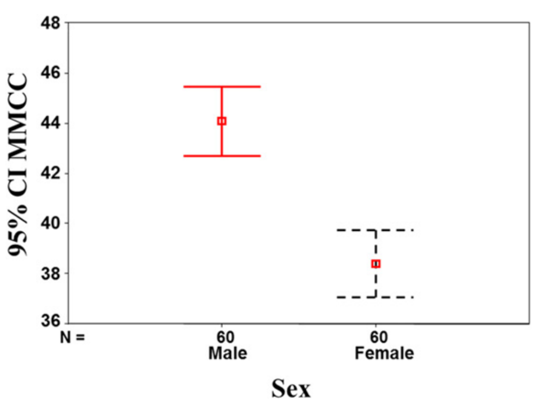

Fig. 3. Comparison of the maximum midshaft circumference of clavicle (MMCC) between male and female (95% CI).

Table 2
Comparison of anthropometric dimensions of clavicle between different age groups (in mm).

Clavicle Parameters	Age (Year)	Mean	SD	95% CI Lower Bound	95% CI Upper Bound	Min	Max
MLC[a]	≤40	139.795	11.5953	136.036	143.554	120.5	162.3
	41–60	141.485	13.7133	137.039	145.930	118.3	168.2
	>60	135.352	12.2520	131.534	139.170	103.4	161.6
MMCC[b]	≤40	41.08	6.015	39.13	43.03	28	53
	41–60	42.38	6.260	40.36	44.41	32	62
	>60	40.29	5.718	38.50	42.07	32	53

[a] MLC: Maximum Length of Clavicle.
[b] MMCC: Maximum Midshaft Circumference of Clavicle.

Table 3
Comparison of sensitivity and specificity of demarking point (D.P) of each dimension of clavicle in determining gender.

Clavicle Parameters	Demarking point (DP)	Sensitivity	Specificity
MLC	Female < 136.250 < male	85%	76.7%
MMCC	Female < 41.50 < male	73.3%	78.3%
MLC + MMCC	Female < 177.6 < male	88.3%	85%

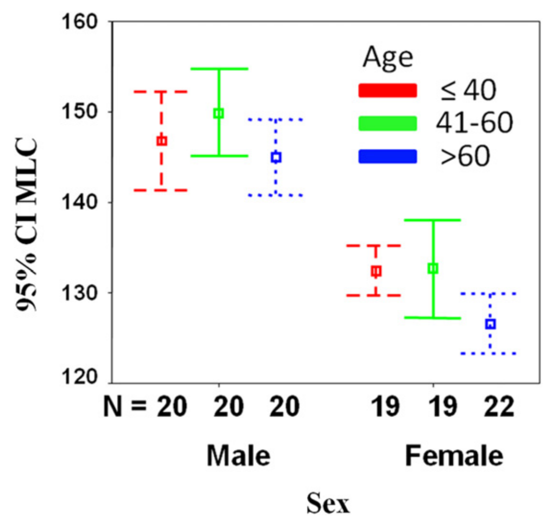

Fig. 4. Comparison of the maximal length of clavicle (MLC) between male and female at different age groups (95% CI).

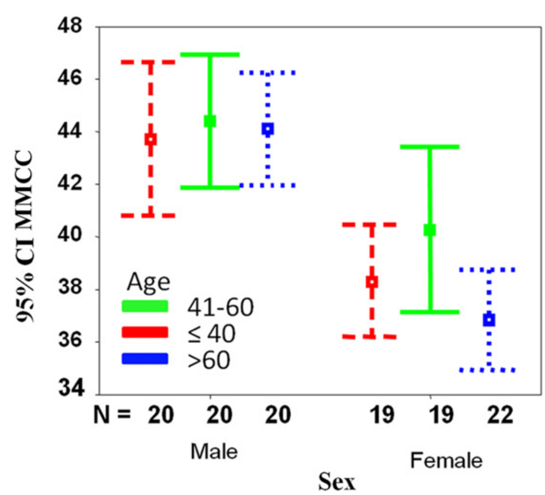

Fig. 5. Comparison of the maximum midshaft circumference of clavicle (MMCC) between male and female at different age groups (95% CI).

Table 4
Comparison of sensitivity and specificity of demarking point (D.P) of Anthropometric parameters of clavicle in different age groups.

Clavicle Parameters	Age Group (Year)	Demarking point (D.P)	Sensitivity	Specificity
MLC[a]	≤40	Female < 136.350 < male	80%	73.7%
	41–60	Female < 140.350 < male	80%	73.7%
	>60	Female < 133.80 < male	90%	86.4%
MMCC[b]	>60	Female < 40 < male	85%	81.8%

[a] MLC: Maximum Length of Clavicle.
[b] MMCC: Maximum Midshaft Circumference of Clavicle.

41–60 years old). Demarking Point for groups with significant difference in anthropometric parameters between two sexes was obtained as described in Table 4.

Logistic regression method was used to determine sex based on the above mentioned variables. It was clarified that sex can be determined just by having two variables including MLC and MMCC using the following formula:

$$G = [(-0.163) \times \mathrm{MLC}] + [(-0.129) \times \mathrm{MMCC}] + 27.861 \qquad (3)$$

It yields that for G values less than 0.5, the bone belongs to a man, while for G values greater than 0.5, the bone belongs to a woman with 95% probability.

G is a metric to predict the gender of the considered bone. For example, in case of MMCC = 42 and MLC = 145, it gives the G value equals to -1.192 that is less than 0.5. Therefore with a 95% probability, the bone belongs to a male. In case of MMCC = 35 and MLC = 130, G is calculated as 2.156 that is greater than 0.5, then the considered bone with a 95% probability belongs to a female.

4. Discussion

Sex determination using human skeletal remains is one of the most important components in forensic identification and starting point of anthropologic researches. Previous studies have shown that various communities have different skeletal anthropometric parameters according to their race and sex.[20] Sex determination is the most significant information which can be obtained from bones. In previous studies, morphologic methods were mostly used to determine sex. However, metric measurements were preferred due to their easy repeatability, high accuracy, and no requirement for special skills.

When pelvis and skull bones are not available, long bones can be useful in determining sex.[21] In this research, we investigated clavicle bone. Measurements of most human body bones indicated that men often have greater bone dimensions than women and generally, in the same race the different dimensions of the body of a mature female is about 94% of the male skeleton.[2] This is applicable for the clavicle bone as well and different studies such as Thieme,[12] McCormick,[13] Luise Frutos[15] and our study indicate that the MLC and MMCC are larger in men comparing to women.

Since this research has been carried out on adults, as expected, no significant relation was found in comparing clavicle dimensions at different age groups.

The current study has been carried out on fresh cadavers, so the numerical results are not necessarily consistent with dry skeletal remains.

The index of dimorphism (ID) which is obtained by bone dimensions in men divided by bone dimensions in women multiplied by 100 is always more than 100 $\left(ID = \frac{\text{Bone Dimension in men}}{\text{Bone Dimension in women}} \times 100\right)$. In our study, this was 113 for MLC and 115 for the MMCC. Measured ID index in Luise Frutos[15] and McCormick et al.[13] studies, was a little smaller but consistent with Thieme study.[12] The disparity can be due to genetic differences and also environmental factors affecting the growth and activity pattern in men and women.

Tables 5 and 6 illustrate clavicle dimensions and clavicle accuracy in both sex in our study and previous reports.

As it is shown, mean maximal length of clavicle in the current study is less compared to Thieme et al.[12] and McCormick et al.[13] studies and it is almost similar to Luise Frutos study.[15] However the mean value of MMCC (μ_{MMCC}) in our study was more than other studies. This is attributed to the racial differences, and environmental factors affecting the growth or sampling method of the studied population.

Sex determination accuracy in our study was more than Jit and Singh[11] study due to racial differences and used method while it was less than McCormick et al.,[13] Jit and Singh,[14] Murphy et al.,[16] Luise Frutos[15] studies that is attributed to less mixed population in their studies and different analysis and statistical methods. However in our study similar to McCormick et al.,[13] and Luise Frutos[15] studies, considering simultaneous impact of two above mentioned parameters, sex determination accuracy increases (Table 3).

In this study, it was observed that the sensitivity of the maximum length of the bone was more than MMCC for sex determination while the specificity of MMCC compared to bone length was negligible.

Table 5
Comparison of clavicle dimension in both sexes between our study and pervious reports.

Sex	Study	Frutos[15]		McCormick[13]		Thieme[12]	Our study	
	Parameter	MLC	MMCC	MLC	MMCC	MLC	MLC	MMCC
Males	Mean	146.77	34.5	159	40.7	158.24	147.208	44.07
	SD	0.811	0.275	0.91	0.38	10.06	10.374	5.35
	Max	161	41	–	–	–	168.2	59
	Min	128	3	–	–	–	126.1	28
Females	Mean	127.48	29.34	141	33.6	140.28	130.370	38.38
	SD	0.876	0.316	0.77	0.28	7.99	8.609	5.26
	Max	144	4	–	–	–	158.1	62
	Min	114.8	2.5	–	–	–	103.4	32

Table 6
Comparison of clavicle value for sex determination between previous studies and our study.

Study	Country	Year	Method	Overall accuracy	Accuracy in men	Accuracy in women
Jit & Singh[11]	India	1966	Measurement of length & circumference of clavicle	–	8%	14%
McCormick etal.[13]	North America	1991	Measurement of length & circumference of clavicle	93%	94%	84%
Jit & Singh[14]	India	1996	Measurement of volume, weight, length & circumference of clavicle	–	80.54%	86.69%
Murphy etal.[16]	New Zealand	2002	Measurement of length & width of the two end of clavicle	–	97.7%	–
Frutos[15]	Guatemala	2002	Measurement of length & circumference of clavicle	85.6–94.8%	87–96.8%	82.8–94.6%
Our study	Iran	2009–2010	Measurement of length & circumference of clavicle	73.3–88.3%	_	_

Furthermore, we used Logistic Regression method to determine sex, in which sex is determined by having only two variables (MLC and MMCC) using the following formula:

$$G = [(-0.163) \times \text{the maximum length of clavicle}] + [(-0.129) \times \text{the midshaft circumference of clavicle}] + 27.861 \quad (4)$$

5. Conclusion

The results of this research indicate that sex can be determined using clavicle dimensions with relatively high accuracy, if just clavicle bone is available due to explosion, plane crashes, mutilated bodies, etc.

The current study has been carried out on fresh cadavers, so in dry skeletal remains, these results should be applied with caution.

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None declared.

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Conflict of interest
None declared.

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